Magnetic Switching by Spin Injection

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INTRODUCTION

Spin-polarized currents provide a new method of efficiently manipulating nanoscale magnetic domains utilizing the short range and strong electronic exchange interaction. The spins of the injected electrons generate a torque on the magnetization of a ferromagnetic film, which at sufficiently high current densities is capable of switching a magnetic domain. We have started a program to directly observe the magnetic switching process during the spin injection process by means of static and time resolved photoemission electron microscopy utilizing the PEEM-2 microscope on beamline 7.3.1.1.

SAMPLES

One crucial parameter for successful switching by spin injection is a high current density. This can be easily achieved when the current flow is restricted to nano-contacts. In our samples, several 50 nm diameter channels are drilled into a 30 nm thin Si_3N_4 membrane using a focused ion beam. These holes are then filled by copper deposition from both sides, forming nano-contacts. The sample structure and preparation is illustrated in Figure 1.

When a voltage is applied between the front and the back of the membrane, the current has to pass through these nano-contacts. This gives rise to a high current density at the location of the channels, falling off inside the film with distance from the center. A spin polarized current is generated by passing the electrons through a ferromagnetic thin film "polarizer" that is aligned unidirectionally by exchange bias. The "polarizer" is decoupled from a second ferromagnetic thin film "sensor" by a copper interlayer, so the two films are magnetically independent. The micromagnetic configuration of the "sensor" film, which is deposited on top of the structure, is then observed with PEEM-2 as a function of the spin polarized current density.

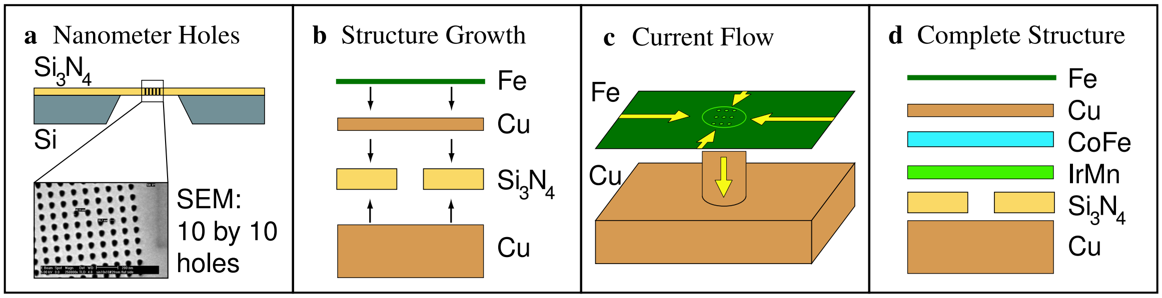

Figure 1: Sample structure for spin injection experiment. **a**: several 50 nm diameter holes are drilled into a Si_3N_4 membrane using a focused ion beam. **b**: Cu is then deposited from both sides, forming nano-contacts. **c**: a current is passed through the Cu filled channels in the membrane and the thin films. **d**: the complete structure, utilizing an exchange biased CoFe/IrMn film as electron polarizer, a Cu buffer layer, and a Fe sensor layer.

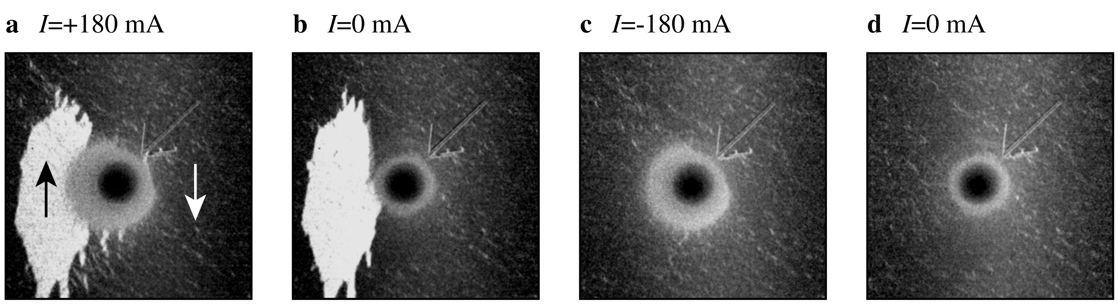

Figure 2: PEEM image at Fe L_3 peak divided by image at Fe L_2 in order to obtain magnetic contrast. The image size is 45 μm. The magnetic axis is along the vertical direction, white corresponds to up and black corresponds to down magnetization (see arrows in **a**). An arrow on the sample points towards the location of the Cu channels. The image series corresponds to different currents through the sample: **a**: the current is able to generate a white domain, which was not present before, it stays when the current is turned off (**b**). **c**, **d**: by reversing the current direction the domain vanishes.

PRELIMINARY RESULTS

First measurements were performed on a sample consisting of Cu channels with a single 8 Å thick magnetic Fe film on top, as shown in Figure 1**b**. A rather large current of up to 180 mA (corresponding to a current density of $j \approx 10^{12}\mathrm{A/m^2}$) was passed through 100 Cu filled channels in the membrane, which destroyed the center region locally (dark circle). However, the measurement demonstrated that the current passes through the Cu channels, and that imaging with PEEM-2 is possible during the injection of a current. The observed switching of a white domain on the left of the channels is due to Oersted-type fields generated by the current. A gray ring around the center region indicates heat generation: the local temperature reached the Curie point, causing loss of magnetic signal.

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